Seismic Analysis of a Tall Structure Considering Diagrid and Tuned Dampers using ETABS

ANANT RAM MISHRA[1]

[1]Student of M.Tech, Department of Civil Engineerin, SAM COLLEGE OF ENGINEERING AND TECHNOLOGY, BHOPAL, (M.P), India

---

● **Abstract -** *The present study is an effort towards analysis of the structure located on a flat ground during the earthquake. An ordinary moment resisting building of G+19 story's located over a medium soil is considered. Comparative analysis is presented for a conventional structure with and without dampers against reaction of diagrid structure with and without damper. The number of bays will be kept as 6 along both direction and the bay size will be kept as 4m with the story height being 3m. The building will be analysed considering zone III by static equilibrium method using ETABS 2015 software. The aim of the study is to evaluate the response of a diagrid and damper system arrangement, to determine seismic parameters that are time period, modes of vibration, base shear, story displacement, story drift and story stiffness, to determine the effectiveness of combination of dampers and diagrids in comparison to conventional structure.*

1.INTRODUCTION

The quick development of the metropolitan populace and subsequent tension on restricted space has impressively impacted the private advancement of the city. The significant expense of land, the craving to stay away from ceaseless endless suburbia, and the need to protect significant horticultural creation have all added to private structures up. As the stature of a structure expands, the lateral load opposing framework turns out to be a higher priority than the underlying framework that opposes the gravitational burdens. The horizontal burden opposing frameworks that are generally utilized are the inflexible edge, shear divider, divider outline, propped tube framework, outrigger framework and rounded framework. As of late, the diagrid – Diagonal Grid – the primary framework is generally utilized for tall steel structures because of its underlying productivity and stylish potential given by the novel mathematical design of the framework. Diagrid has a decent appearance and it is handily perceived. The design and effectiveness of a diagrid framework diminish the quantity of underlying components needed on the façade of the structures, thusly less check to the external view.

1.1Diagrid structures

The diagrid underlying framework can be characterized as a corner-to-corner part shaped as a system made by the crossing point of various materials like metals, concrete or wooden pillars which are utilized in the development of structures and rooftops. Diagrid designs of the steel individuals are proficient in giving arrangements both as far as strength and solidness. Yet, these days a far-reaching use of diagrid is utilized in the enormous range and elevated structures, especially when they are complex calculations and bent shapes.

1.2 Module Geometry of Diagrid Structural System

Diagonal membrane from the diagrid conveys both shear and second. So the ideal point of putting the diagonals is reliant upon building stature. The ideal point of the segments for greatest twisting inflexibility in the typical structure is 90 degrees and for the diagonals for shear, unbending nature is 35 degrees. It is expected that the ideal point of the diagrid falls in the middle of the both. Typically, the received reach is 60 - 70 degrees. As the stature of the structure expands the ideal point additionally increments.

1.3 Diagrid Structural System Node Design

The hubs are a significant piece of the plan of the diagrid framework. Every one of the corner to corner areas are associated with one another with the assistance of hubs. These hubs are intended for two sorts of burdens, vertical burden and even shear. These hubs are joined to different areas by welding or shooting. It is ensured that exceptionally less measure of the weld is to be utilized in the joining. The upward burden is moved as pivotal burdens from the diagrid individuals that are set over the hubs to the gusset plate and stiffeners, then, at that point to the diagrid individuals beneath the hubs. The level shear is additionally as pivotal burdens in the diagrid over the hubs, however here one is in pressure and another is in strain. The exchange of burden is from over the hub part to the gusset plate and stiffener and afterwards from the gusset plate and stiffener to the individuals beneath the hub in a couple of pressure and strain. Because of this heap move way, the shear powers created at the area of the bolt association are exceptionally high under the hour of sidelong loads. This might be the shear zone or feeble zone of this construction during the seismic tremors, the planning of the bolt associations is to be done cautiously.

2. Literature Review

Saman Sadeghi and Fayaz R. Rofooei,(2020) the paper explored that respect, the impacts of BRBs on the seismic execution qualities of diagrids, for example, reaction alteration factor, R, overstrength factor, Ω0, pliability proportion, μ, and middle breakdown limit, ^ SCT, are assessed. To this end, 6 three dimensional diagrid structures with different statures and inclining points are displayed utilizing the OpenSees program and are furnished with BRBs in an original game plan. Using nonlinear static investigation, the seismic presentation components of models are assessed. In this way, the middle breakdown limit (^ SCT) of the models are dictated by performing nonlinear powerful investigations.

Bhavani Shankar and Priyanka M V (2018), the new investigation examination was made on concrete diagrid building and ordinary structure of comparative arrangement size (15x15)m and the investigation was made on the reaction of the construction by differing the story range from G+5 to G+15. Another examination was completed for diagrid and traditional constructions of comparative arrangement size (18x18)m with same story stature G+15, and the impact of point of diagrid and length of diagrid was contemplated and was contrasted and the customary framework.

Avnish Kumar Rai & Rashmi Sakalle,(2017) in the given exploration they contributed that the steel diagrid structure at an external bit of the structure at 60 degrees having an internal centre of R.C.C segments with R.C.C shaft and the section was dissected and contrasted and a regular substantial structure. The inclining individual from the diagrid structure moved the sidelong loads by hub activity contrasted with the bending of vertical segments in the regular structure framework. A normal eleven-story RCC working with an arrangement size of 16 m × 16 m situated in seismic zone V and III are considered for investigation. STAAD.Pro programming is utilized for displaying and investigation of primary. The seismic zone was considered according to IS 1893.

3. Problem Statement

3.1 Building Geometry

Table 3.1 Geometry of the Structure

Building Type	Commercial
Plan Area	45x45m
No. of Story	G+19
Height of Story	3m
Core Thickness	400mm
Angle of diagrid	67.4°
Size of columns:	500mmX500mm
Size of beams	300mmX500mm
Thickness of slab	120mm

Size of Diagonals:	300X500
Size of steel square tube section used for Diagrid	385.6mm X 385.6mm X 11mm
Support Type	Fixed

3.2 Loading Condition

All loading are done in accordance to Indian Standards.

Load Combination

1) 1.5 (DL + LL)

2) 1.2 (DL + LL ± EL)

3) 1.5 (DL ± EL)

4) 0.9DL ± 1.5EL

Live load – 4kN/m2 as per IS-875(Part 2)

Seismic Load

Table 3.3 Seismic Load

Zone Factor	0.16 (III)
	1.5
	5
Soil Type	III

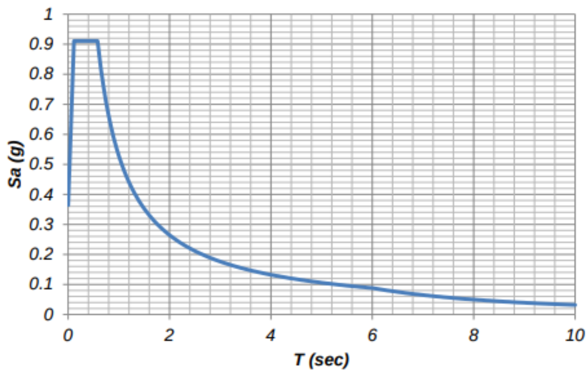


Fig 3.4 Seismic Capacity

3.3 Structural Analysis

The following are preliminary analyses to identify the behavior of the prototype diagrid building and determine if the building is adequate as a basic input of this study.

3.4.1 Natural Period and Mode Shapes of the Structure

To fulfill the requirements of 90% mass participation ratios, 24 modes are used for the basic diagrid model while 48 modes are used for the diagrid model with TD units. The latter has more modes due to additional modes generated by TD. Figure 3.5 shows the four modes of interest that characterize the building behavior under earthquake events. Those modes are holding the biggest percentage of mass participation factors on each major direction except UZ (vertical direction). Table 3.1 shows the first seven vibration periods of the building with their respective modal participation factors that represent the four main mode shapes of the building. The total mass participation ratios for each directions of the prototype building model accounting for the 24 modes are:

UX = 95.87% > 90%

• UY = 96.03% > 90%

• UZ = 86.68%

• RX = 99.96% > 90%

• RY = 99.95% > 90%

• RZ = 94.29% > 90%

4. Methodology

4.1 General

The present study is an effort towards analysis of the structure located on a flat ground during the earthquake. An ordinary moment resisting building of G+19 story's located over a medium soil is considered. Comparative analysis is presented for a conventional structure with and without dampers against reaction of diagrid structure with and without damper. The number of bays will be kept as 6 along both direction and the bay size will be kept as 4m with the story height being 3m. The building will be analysed considering zone III by static equilibrium method using ETABS 2015 software. The details of models are given as follows

Plan dimension-20mx20m

Number of stories-G+19

Floor to floor height-3m

Number of bays in X-direction-9

Number of bays in Y-direction-9

Depth of slab-150mm.

4.2 Modelling

Step 1: ETABS provide an eco system to model structure using different grids as per plan

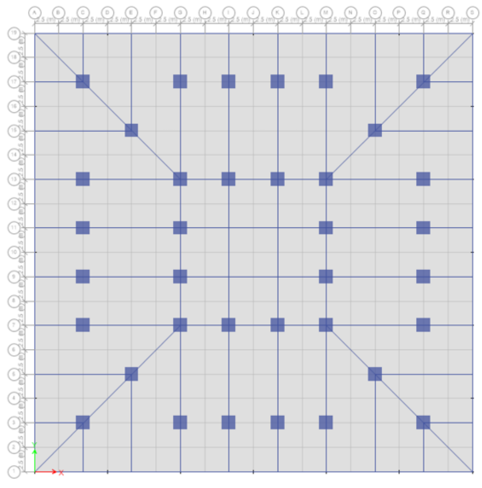


Fig 4.1 Grid Designing of the different cases.

Step 2: This step includes defining material and section properties of beams and column as per the geometry of the structure which was previously described in chapter above.

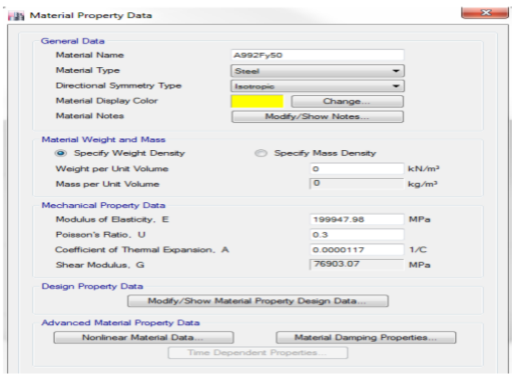


Fig Defining Material Properties

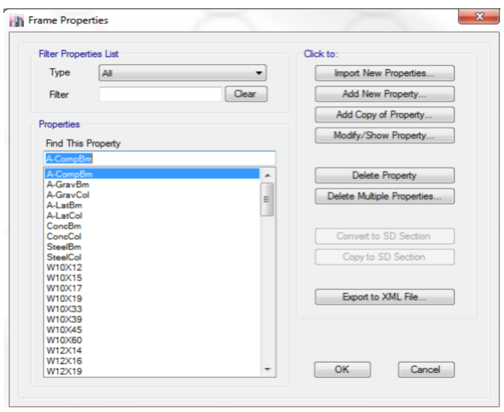


Fig Defining Section Properties

p 3: Fixed support are provided at the bottom of the structure

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 12 | Dec 2021 www.irjet.net p-ISSN: 2395-0072

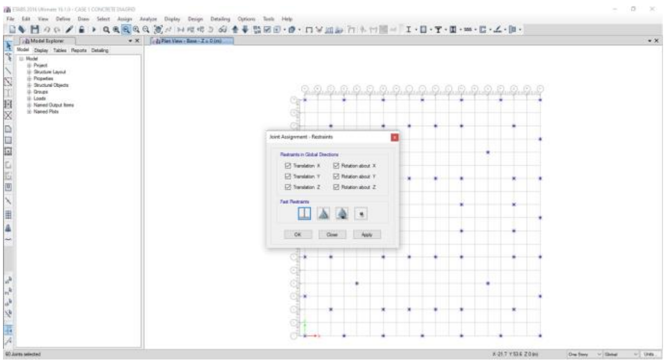


Fig Assigning Fixed Support in X, Y and Z direction.

Step 4 Defining Load condition

Step 5: Analyzing the results

5. Results and Discussion

5.1 Time Period

The natural period (Tn) of a building is the time it takes to go through a complete vibration cycle. This is the inherent nature of the building controlled by its mass "m" and stiffness "k". These three astrological signs are interconnected.

$T_n = 2\pi\sqrt{m/k}$

Its unit is second. Buildings that are heavy and flexible have more natural period than light and stiff buildings.

Table 5.1 Natural Time Period in second

Story Drift in mm				
Story	Conventional Structure	CS with Damper	Diagrid Structure	DS with Damper
1	0.243	0.158	0.138	0.111
2	0.793	0.708	0.688	0.661
3	0.992	0.907	0.887	0.86
4	1.021	0.936	0.916	0.889
5	1.443	1.358	1.338	1.311
6	1.721	1.636	1.616	1.589
7	1.982	1.897	1.877	1.85
8	2.345	2.26	2.24	2.213
9	2.509	2.424	2.404	2.377
10	2.876	2.791	2.771	2.744
11	3.987	3.902	3.882	3.855
12	4.284	4.199	4.179	4.152
13	4.321	4.236	4.216	4.189
14	3.943	3.858	3.838	3.811
15	3.667	3.582	3.562	3.535
16	3.261	3.176	3.156	3.129
17	2.908	2.823	2.803	2.776
18	2.867	2.782	2.762	2.735
19	2.76	2.675	2.655	2.628
20	2.6409	2.5559	2.5359	2.5089

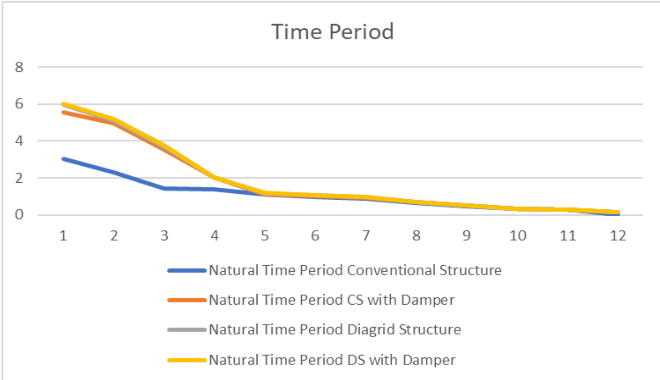


Fig 5.1 Fundamental Time Period

5.2 Story Drift

It is the displacement of one story relative to the other story above or below. The story drift in any story due to the minimum specified design lateral force, with partial load factor of 1, shall not exceed 0.004 times the story height or (h/250).

In Eurocode 8:2004 Part 1 specifies allowable maximum story drift is 1% of story height therefore as per Eurocode permissible limit of drift will be 0.01 X 3000 = 30 mm.

Table 5.2 Storey Drift in mm

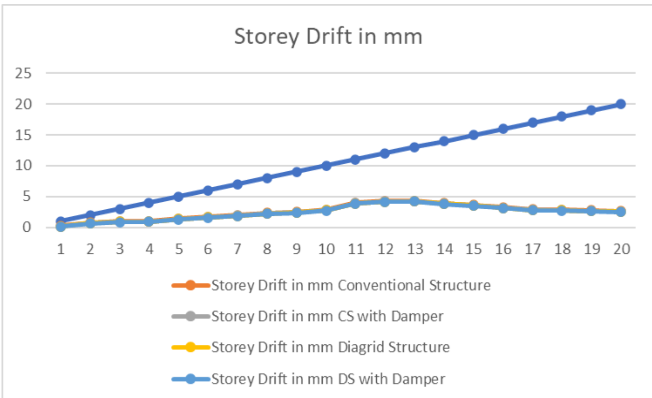
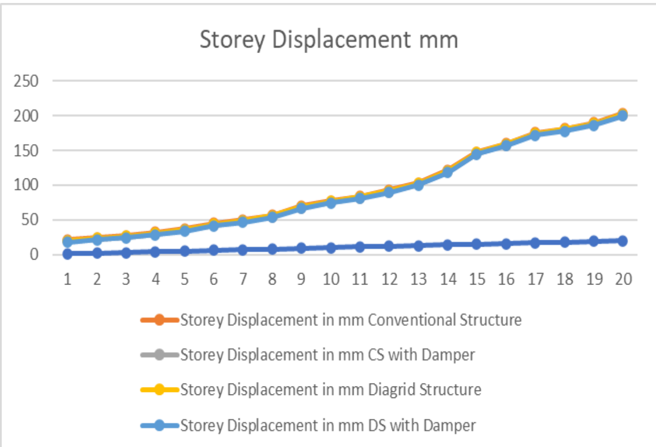


Fig 5.2 Story Drift in mm

5.3 Story Displacement

It is total displacement of the story with respect to ground. According to IS 1893:2016 Clause deformations, the maximum allowable deflection is calculated as H/250, where h is the height of the story from the ground level. In Eurocode 8:2004 specifies allowable maximum story displacement is H/100.

Story Displacement in mm				
Story	Conventional Structure	CS with Damper	Diagrid Structure	DS with Damper
1	21.3421	19.0211	20.2552	17.9998
2	24.5347	22.2137	23.4478	21.1924
3	27.438	25.117	26.3511	24.0957
4	31.7934	29.4724	30.7065	28.4511
5	36.9834	34.6624	35.8965	33.6411
6	44.7995	42.4785	43.7126	41.4572
7	49.9792	47.6582	48.8923	46.6369
8	56.782	54.461	55.6951	53.4397
9	69.9237	67.6027	68.8368	66.5814
10	77.5893	75.2683	76.5024	74.247
11	83.9832	81.6622	82.8963	80.6409
12	92.743	90.422	91.6561	89.4007
13	103.247	100.926	102.1601	99.9047
14	121.567	119.246	120.4801	118.2247
15	147.823	145.502	146.7361	144.4807
16	159.869	157.548	158.7821	156.5267
17	175.389	173.068	174.3021	172.0467
18	181.295	178.974	180.2081	177.9527
19	189.823	187.502	188.7361	186.4807
20	203.211	200.89	202.1241	199.8687



5.4 Base Shear

IS 1893:2016 (Part I) Auto Seismic Load Calculation: This calculation presents the automatically generated lateral seismic loads for load pattern EQ-X and EQ-Y according to IS 1893:2016.

Vb = Ah x W

Where, Ah= Design horizontal seismic coefficient for structure

W= Seismic weight of the building.

Where, R=response reduction factor.

Z= zone factor.

I= importance factor.

Sa/g=average acceleration response coefficient.

Model	Base Shear (kN)
Conventional Structure	2103.8416
CS with Damper	2523.47
Diagrid Structure	2520.6485
DS with Damper	2212.462

5.5 Story Stiffness

The term story stiffness is defined as the capability of resisting force/load acting on any story. It depends on material property, if the story is stiffer it means less flexible.

Story Stiffness				
Story	Conventional Structure	CS with Damper	Diagrid Structure	DS with Damper
1	23603161.1	1192357	23603049.1	989255.573
2	13288034.4	1100669	13287922.4	911726.623
3	9522210.36	1012978	9522098.36	880606.49
4	7504235.74	982994	7504123.74	847875.789
5	5324383.12	953670	5324271.12	813968.332
6	4430231.54	925661	4430119.54	785484.175
7	3798684.67	897729	3798572.67	755676.824
8	3341982.9	869698	3341870.9	727736.724
9	3089083.22	841696	3088971.22	701896.915
10	2716899.78	814024	2716787.78	677241.584

11	2430767.13	787047	2430655.13	653650.96
12	2233971.77	761102	2233859.77	630998.566
13	1866556.25	736439	1866444.25	609273.233
14	1634992.38	713176	1634880.38	588471.647
15	1453101.15	691306	1452989.15	568593.547
16	1357240.11	670728	1357128.11	549627.73
17	1327421.21	651296	1327309.21	531555.69
18	1221694.59	632868	1221582.59	514357.33
19	1122616.59	615337	1122504.59	498017.136
20	1077312.9	598642	1077200.9	482526.738

6. Conclusion and Future Scope

6.1 Conclusion

Response spectrum analysis results provides a more realistic behavior of structure response and diagrid structure is more effective in lateral load resistance Seismic and wind analysis of conventional building with TMD and diagrid structure with TMD with equivalent plan area at seismic zone III is carried out and the following conclusions are drawn from the study:

- Total base shear increases in the circular form of diagrid constructing and decreases in square and triangular form of diagrid constructing while comparing with traditional constructing for seismic analysis.
- The node displacement decreases in all shapes of diagrid buildings whilst examined with conational kind of building.
- Maximum Centre shear stresses in slab SQX and SQY are increased in diagrid buildings with flat slab as compared to conventional building and diagrid building without flat slab.
- Maximum bending moment at the middle of the slab i.e. MX, MY & MXY more growth in diagrid construction as examined to standard construction.
- Similarly, Principal, Max Von Mis and Tresca stresses at top and bottom of the slab more increase in diagrid building as compared to conventional building but slightly increases in flat slab diagrid building.
- It's found that the total base shear decreases 5% in diagrid building with conventional slab and decreases 15% in flat slab diagrid Building while comparing with traditional building for seismic analysis.
- It concludes that the node displacement decreases in both diagrid buildings i.e with and without flat slab whilst examined with conational kind of building.
- The values of story drift are found to be within permissible limit i.e. not more than 0.004 times the story height as per norms according to IS 1893:2002 (Part-1) for seismic analysis.
- Its concluded Diagrid building shows less lateral displacement and drift in comparison to conventional building.

6.2: Future Scope:

In this study following future scopes can be consider as:

1. In this study we are considering tall structure whereas stability in low height of mid rise structures can be justify in future with same conditions.
2. In this study seismic loading is considered whereas in future wind load or thermal load can be utilize.
3. In this study ETABS software is used whereas in future SAP2000 or tekla structure can be preffered.

REFERENCES

1.) Andre R. Barbosa and Garlan Ramadhan,[Seismic Performance of a Tall Diagrid Steel Building with Tuned Mass Dampers],2014 EDUGAIT Press.

2.) Jayesh Akhand and J.N Vyas,[Comparative Study of Different shapes of Diagrid Structure System with Conventional System using Response Spectrum Analysis],International Research Journal of Engineering and Technology (IRJET),Apr 2019.

3.) Sunil Gurdekar and Mayur Singi,[Dynamic Analysis of Flat Slab Diagrid Structure with Response Spectrum Method],Mukt Shabd Journal 2020.

4.) Manthan I. Shah, Snehal V. Mevada and Vishal B. Patel,[Comparative Study of Diagrid Structures with Conventional Frame Structures],Int. Journal of Engineering Research and Application, May 2016

5.) Ravish Khan and S.B. Shinde,[ANALYSIS OF DIAGRID STRUCTURE IN COMPARISON WITH EXTERIOR BRACED FRAME STRUCTURE],International Journal of Research in Engineering and Technology,2015

6.) Garlan Ramadhan and André R. Barbosa,[IMPROVING THE SEISMIC PERFORMANCE OF DIAGRID STEEL STRUCTURES USING FRICTION MASS DAMPER], National Conference in Earthquake Engineering, Earthquake Engineering Research Institute, Anchorage, AK, 2014.